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BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES
Paper No. 13

Application Number: 08/995,108
Filing Date: December 19, 1997
Appellant(s): Peijun Ding et al.

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GROUP 1700

Shirley L. Church
For Appellant

EXAMINER'S ANSWER

This is in response to Appellant's brief on appeal filed November 21, 2000.

(1) Real Party in Interest

A statement identifying the real party in interest is contained in the brief.

(2) Related Appeals and Interferences

A statement identifying the related appeals and interferences which will directly affect or be directly affected by or have a bearing on the decision in the pending appeal is contained in the brief.

(3) Status of Claims

The statement of the status of the claims contained in the brief is correct.

(4) Status of Amendments After Final

The appellant's statement of the status of amendments after final rejection contained in the brief is correct.

(5) Summary of Invention

The summary of invention contained in the brief is correct.

(6) Issues

The appellant's statement of the issues in the brief is correct.

(7) Grouping of Claims

Appellant's brief includes a statement that claims 8-27 do not stand or fall together and provides reasons as set forth in 37 CFR 1.192(c)(7) and (c)(8).

(8) Claims Appealed

The copy of the appealed claims contained in the Appendix to the brief is correct.

(9) Prior Art of Record

The following is a listing of the prior art of record relied upon in the rejection of claims under appeal.

5,391,517	GELATOS et al	2-1995
5,676,587	LANDERS et al	10-1997
4,985,750	HOSHINO	1-1991

5,707,498	NGAN	1-1998

(10) Grounds of Rejection

The following ground(s) of rejection are applicable to the appealed claims:

Issue 1: Claims 8-17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Gelatos *et al* (U.S. Pat. 5,391,517) in view of Landers *et al* (U.S. pat. 5,676,587).

Gelatos *et al* teaches a method of producing barrier layer for the subsequent deposition of an overlaying conductive layer. A first layer of TiN_x [18] is deposited followed by a second layer of Ti [20]. (Figure 3, col. 3 lines 39-60) The first and second layers are each specifically disclosed to have a thickness of 100-300 Å which is within the instant range. (col. 3 line 68, col. 4 line 4, respectively) As disclosed in the reference, the first and second layers comprise the upper layers of a composite interface layer [22]. A copper conductive layer [24] is deposited over the uppermost surface of the interface layer [22], i.e. the copper conductive layer [24] is directly deposited onto the surface of the second layer [20]. (col. 4 lines 30-38) The copper conductive layer is deposited while keeping the temperature of the susceptor, i.e. substrate holder at a temperature of 190°C which meets the instant less than 500 °C. (Col. 5 lines 10-12) Additionally, it was set forth by the examiner that the upper range within 500 °C would have been inherently present in sputtering due to ohmic heating of the wafer as well as heating from the harsh environment of the sputtering plasma. The interface layer [22] is specifically disclosed to be formed via sputtering. (Col. 3 lines 61-62)

Gelatos *et al* does not explicitly teach employing Ta and TaN as components of the interface layer [22]. However, Gelatos *et al* clearly suggests that Ta can be employed as part of the interface layer. (Col. 3 line 56 *et seq*)

The teachings of Landers *et al* here follows. Landers *et al* similarly teaches an interface layer [12] wherein either a Ta/TaN layer or a Ti/TiN layer is employed as a barrier layer. (Col. 3 lines 10-39, Figure 1) Thus, Ta/TaN and Ti/TiN interface layers are submitted as art-recognized equivalents in regards to functioning as an underlying refractory metal layer for a subsequent deposition of copper. In Landers *et al*, the copper layer [10] is specifically disclosed to be deposited over the interface layer. Landers *et al* is relied upon to teach that the combination of a refractory metal, e.g. Ti or Ta, and its respective nitride, e.g. TiN or TaN is well-known for use in an interface layer or barrier layer. Thus, the skilled artisan would have found it obvious to modify the invention of Gelatos *et al* by employing Ta and its corresponding nitride as part of the barrier layer for reasons such as prevention of diffusion and electromigration of the overlaying copper layer.

As to a TaN_x layer wherein x ranges from about 0.1 to about 1.5, this limitation is considered an obvious range since a stoichiometric amount of TaN would have Ta and N present at a 1:1 ratio, e.g. wherein x equals 1.0.

Issue 2: Claims 8-17 and 21-26 are rejected under 35 U.S.C. 103(a) as being unpatentable over Hoshino (U.S. Pat. 4,985,750) in view of Landers *et al.*

Hoshino teaches a method of producing barrier layer for the subsequent deposition of an overlaying conductive layer. In reference to Figure 2, a first layer [20] of the barrier layer is deposited by a traditional sputtering method followed by the deposition of a second layer [22], the second layer specifically disclosed to be a Ta layer having a thickness in the range of 500 to 3000 Å. A conductive layer of copper [24] is then deposited over the barrier layer. (Col. 3 lines 28-66) The copper (Cu) layer is also deposited by a physical vapor deposition technique such as sputtering, then annealed at a temperature of less than 500 °C. (Col. 4 lines 3-13 and 38-40)

Hoshino does not explicitly teach the first layer to be TaN. However, Landers *et al* as discussed above teaches that a Ta/TaN combination for a barrier layer is well-known and desired as the underlying barrier layer for a subsequent copper metallization overlay. A modification of Hoshino's invention would therefore result in the first layer being a TaN layer while retaining the second layer of Ta as already disclosed by Hoshino. The resulting modification would be a TaN/Ta structure. Thus, it would have been obvious to one of ordinary skill in the art to modify Hoshino's invention by employing a first layer of TaN, because Landers *et al* teaches that a TaN layer/Ta layer combination is well known in the art in the manufacture of copper interconnect structures and would have been desired for reasons such as effective prevention of diffusion and electromigration.

Hoshino does not explicitly teach a Cu crystallographic content being at least 70% of the Cu <111> crystallographic content which can be obtained by depositing copper over a pure Ta barrier layer, and a substrate temperature of less than about 500 °C. However, as to a Cu crystallographic content being at least 70% of the Cu <111> crystallographic content, it is considered that the copper layer as taught by Hoshino has at least 70% of the Cu <111> crystallographic content, since in Hoshino's invention the copper layer is overlayed onto a tantalum layer ranging from 500 angstroms to 3000 angstroms. Applicant discloses and claims that a copper laying having at least 70% of the Cu <111> crystallographic content can be obtained by depositing the copper layer using a pure Ta barrier layer which is about 500 Å thick. (See, for example, claim 21 lines 2-5) Since in Hoshino's invention the copper is deposited onto a Ta layer ranging from 500 to 3000 Å, it is reasonably presumed that a copper layer deposited onto a Ta layer of the same thickness as that which is claimed would consequently form a copper layer having at least 70% of the Cu <111> crystallographic content.

Issue 3: Claims 18-20 are rejected under 35 U.S.C. 103(a) as being unpatentable over Gelatos *et al* in view of Landers *et al* as applied to claims 8-17 above, and further in view of Ngan (U.S. Pat. 5,707,498).

The teachings of Gelatos *et al* and Landers *et al* are discussed in detail above.

Gelatos *et al* does not explicitly teach at least a portion of the metal and its corresponding nitride, e.g. Ta layer and TaN_x layer, deposited using ion-deposition sputtering. However, Ngan teaches that in the manufacture of semiconductor devices, ion-deposition sputtering is preferred over traditional sputtering in order to have uniform step coverage and filling of contact hole vias.

(Col. 1 lines 44-56) Of note, Ngan uses ion-deposition sputtering to deposit an elemental metal and its corresponding nitride, such as titanium and titanium nitride. (Col. 7 lines 43-66) Titanium and tantalum, and their respective nitrides, have been established above to be art-recognized equivalents. Thus, it would have been obvious to one of ordinary skill in the art to further modify Gelatos *et al*'s invention by employing ion-deposition sputtering, because Ngan teaches that ion-deposition sputtering improves deposition in semiconductor manufacturing.

Issue 4: Claims 18-20 and 27 are also rejected under 35 U.S.C. 103(a) as being unpatentable over Hoshino in view of Landers *et al* as applied to claims 8-17 above, and further in view of Ngan.

The teachings of Hoshino in view of Landers *et al* are discussed in detail above. Ngan is relied upon as a tertiary reference for identical reasons discussed in detail in the immediately preceding paragraph.

Appellant succinctly presents the same arguments to Ngan as discussed and addressed above. In reply, the examiner reiterates the same position set forth above. As to the combination not teaching Ta in contact with an overlaying copper layer, Gelatos *et al* specifically teaches an overlaying copper layer in contact with the metal, e.g. Ta, and not its nitride TaN, while Landers *et al* is relied upon to show either Ti/TiN or Ta/TaN as layers for barrier layer combinations. As to advantages of ion-deposition sputtering, Ngan specifically teaches such advantages in the "Background" section of the disclosed invention, such as increased filling of contact hole vias and increased conformal deposition.

(11) Response to Argument

Response to arguments with respect to Group 1, claims 8-12, 14/8, 14/12 and 15-17

Appellant submits that Gelatos *et al* teaches a three-layer "interface layer", however Appellant is reminded that the ground of rejection relies only on the upper two layers of such a three-layer structure. The present claims do not specify the substrate on which the first and second layers are deposited thereon.

Appellant acquiesces to the suggestion of Gelatos *et al* of other metals being employed as part of the interface layer. Appellant submits that the example shown by Gelatos *et al* would result in Ta as the first layer and not TaN as presently claimed. In reply, the examiner submits that this teaching of Gelatos *et al* was cited as a mere suggestion to employ other refractory metals other than Ti or TiN; such refractory metals including Ta as specifically suggested by Gelatos *et al* and as required in the instant second layer. As set forth above, Landers *et al* is relied upon to teach equivalence of Ti/TiN and Ta/TaN barrier layer combinations.

Appellant submits that Gelatos *et al* creates a copper-titanium intermetallic layer and employs an annealing step. Examiner agrees, however these steps are performed subsequent to the deposition of copper over the Ti layer. (Col. 4 lines 30-38) Examiner notes that Appellant's present claims require "subsequent processing steps"; the annealing step as taught by Gelatos *et al* is specifically disclosed to be employed after copper deposition is complete. (Col. 5 lines 21-26)

Appellant submits that Gelatos *et al* teaches away from the present invention with regards to a substrate temperature of less than 500°C. Appellant, however, appears to rely on the

disclosed temperature ranges of Gelatos *et al* during the annealing step, not during the deposition steps as required by the instant claims. As discussed above, the substrate temperature is specifically disclosed by Gelatos *et al* to be maintained at 190 °C such as found in a cold wall deposition system. (see col. 5 lines 11-13)

Appellant submits that there is nothing in Landers *et al* to suggest that the Ta layer is in contact with the copper layer, and further emphasizes the criticality of the order of deposition as claimed in the present invention. In reply, the examiner submits that although Landers *et al* may not clearly set forth the Ta layer in contact with the copper layer, Landers *et al* specifically teaches a Ta/TaN barrier layer combination. Thus, a modification of the invention of Gelatos *et al* by employing Ta for Ti would result in the copper layer being deposited above the Ta layer. As to ordering of steps, Gelatos *et al* was relied upon as a primary reference in the rejection for this very reason as the instant order of deposition, i.e. metal/metal nitride/copper, was specifically set forth within the disclosure of Gelatos *et al.*

Appellant submits that the examiner's modification of Hoshino's invention by employing its corresponding nitride is not so obvious, asserting that all of the references relied upon by the examiner instead teaches deposition of a first layer of Ta, a second layer of TaN, then an overlaying layer of Cu in that order, i.e. reverse of Appellant's claimed invention. However, while Landers may not explicitly teach the specific order in which the Ta/TaN layer is deposited prior to Cu deposition, a modification of Hoshino by employing such a combination would result in the instant order of deposition, since Hoshino already specifically teaches deposition of Ta as the second layer, followed by Cu deposition. One of ordinary skill in the art would retain the Ta

layer as the second layer in Hoshino's invention since this layer is specifically disclosed to function as a barrier layer for the Cu layer. In fact, both the Ta layer and the overlaying Cu layer are specifically disclosed to also having the same wiring pattern. (Col. 4 line 14 *et seq*)

Appellant submits that the first metal layer was not suggested by Hoshino to include tantalum. In reply, the examiner submits that the instant first layer is not claimed to require tantalum, but rather tantalum nitride. It is the second layer in Appellant's invention which is required to be tantalum. Appellant's apparent error notwithstanding, Landers *et al* as relied upon in the rejection is considered to teach or at least suggest a Ta/TaN barrier layer combination which, when taken in combination with Hoshino, would result in a first layer of TaN (as modified), a second layer of Ta (as specifically taught by Hoshino), and an overlaying Cu layer (as specifically taught by Hoshino).

Arguments directed to Hoshino not addressing interdiffusion or electromigration are not persuasive as these limitations are outside the scope of the present claims.

<u>Response to arguments with respect to Group 2, claims 13 and 14/13</u>

Appellant submits that Gelatos *et al* teaches away from Appellant's claimed invention of a metal nitride such as TaN_x layer having a thickness of 10 Å to 300 Å. However, with respect to the thickness, the specific teaching of Gelatos *et al* of a metal nitride layer having a thickness of 300 Å is actually anticipatory of that value within the instant range. Thus, contrary to Appellant's assertion, Gelatos *et al* is not considered to teach away from the instant range. Of additional note, Appellant's present claims recite "about 10 Å to about 300 Å", thereby rendering

the instant range actually broader in scope than that arguably compared with the teachings of Gelatos *et al.*

Appellant submits that Hoshino teaches a much thicker barrier than that taught and presently claimed. However, Appellant's claims are noted to recite a thickness of "about 10 Å to about 300 Å", thereby rendering the instant range actually broader in scope than that arguably compared with Hoshino's teachings. Thus, while Hoshino expresses a preference for a thicker layer of 500 Å to 3000 Å, it would not require undue experimentation for the skilled artisan to explore thickness levels below that range for reasons such as formation of a semiconductor structure having narrower interconnect leads or reducing circuit geometries to increase transistor speed.

Arguments directed to Hoshino not addressing interdiffusion or electromigration are not persuasive as these limitations are outside the scope of the present claims.

<u>Response to arguments with respect to Group 3, claims 18-20</u>

Appellant submits that the combination of Ngan with Gelatos *et al* and Landers *et al* do not recognize Ta in contact with the overlaying copper layer. In reply, the examiner re-emphasizes that Gelatos *et al* specifically teaches the overlaying copper layer in contact with the metal, e.g. Ta, and not its corresponding nitride TaN. Appellant also submits that the prior art combination does not provide an advantage for using ion-deposition sputtering during deposition of tantalum or tantalum nitride layers. However, ion-deposition sputtering is readily appreciated by the skilled artisan to be preferred over traditional sputtering for reasons such as increased filling of contact hole vias and increased conformal deposition. (see Ngan, col. 1 lines 33-56)

Furthermore, Ngan's specific example of sputtering titanium or its corresponding nitride is considered to be merely illustrative and not restrictive of the refractory metals well-known in the art for use as part of a barrier layer structure. As discussed above, Landers *et al* teaches that Ti/TiN or Ta/TaN are readily known to the skilled artisan as art-recognized equivalents for refractory metals in barrier layer metallurgy. It would not require undue experimentation for the skilled artisan to employ Ta in lieu of Ti, as these metals and their corresponding nitrides are recognized in the art to have the same function and possess identical electromigrative barrier properties when employed within a semiconductor structure.

Arguments directed to Gelatos *et al* and Landers *et al* not mentioning the ion content of the barrier layer material or wetting layer material is not persuasive as this limitation is outside the scope of the present claims.

<u>Response to arguments with respect to Group 4, claims 21 and 22</u>

Appellant once again asserts that all of the references relied upon by the examiner which pertain to the use of a Ta/TaN combination, e.g. Landers *et al*, teaches deposition of a first layer of Ta, a second layer of TaN, then an overlaying layer of Cu in that order, i.e. reverse of Appellant's claimed invention. In reply, the examiner submits that Appellant is interpreting Landers *et al* so that the teachings therein may be construed to teach away from Appellant's invention. Of note, Appellant does not cite any specific portions of Landers *et al* in support of Appellant's apparent speculation. Landers *et al* was relied upon merely to show a Ta/TaN combination; within this ground of rejection, the ordering of steps is preserved within the teachings of Hoshino, which specifically discloses depositing the copper layer over the tantalum

layer. (see col. 4 lines 3-4) One of ordinary skill in the art would retain the Ta layer as the second layer in Hoshino's invention since this layer is specifically disclosed to function as a barrier layer for the Cu layer, with both layers specifically disclosed to also have the same wiring pattern. (Col. 4 line 14 *et seq*)

Appelant submits that the crystalline structure of the copper layer will not be high in <111>, and appears to draw this line of argument based on Appelant's belief that the copper layer in Hoshino's invention is deposited onto a TaN layer. However, as set forth above, the second layer in Hoshino's invention, i.e. Ta, is preserved in the proposed modification, only the first layer is modified to comprise TaN as rendered obvious by Landers *et al.* As to the copper layer having a crystalline structure, examiner notes that Appelant's own disclosure has shown that deposition of copper onto a Ta layer of sufficient thickness would result in the instant crystallographic content. (see specification, page 15 lines 13-19) From the cited portion of Appelant's specification, the examiner notes that a "500 Å thick Ta layer underlying the 1,000 Å thick sputtered copper layer" results in a "relatively high"... "quantity of Cu <111>". As Hoshino specifically teaches this thickness of Ta underlying the Cu layer, it is reasonably presumed based on Appelant's own disclosure that the resulting Cu layer would inherently possess the instant crystallographic content.

Arguments directed to Landers *et al* not mentioning electromigration are not persuasive as this limitation is outside the scope of the present claims.

Response to arguments with respect to Group 5, claims 23-26

Appellant re-submits that Hoshino teaches a much thicker barrier for the Ta layer than that taught and presently claimed. In reply, the examiner re-submits that Appellant's claims are noted to recite a thickness of "about 10 Å to about 300 Å", thereby rendering the instant range actually broader in scope than that arguably compared with Hoshino's teachings. As explained above, while Hoshino expresses a preference for a thicker layer of "about 300 Å", e.g. 500 Å, it would not require undue experimentation for the skilled artisan to explore thickness levels below that range for reasons such as formation of a semiconductor structure having narrower interconnect leads or reducing circuit geometries to increase transistor speed. As to whether or not a Ta layer greater than 300 Å would result in a copper-comprising structure having the crystallographic content claimed, as discussed in the immediately preceeding paragraph Appelant's own disclosure appears to state that a Ta layer greater than 300 Å would have the instant crystallographic content. The examiner further notes that Figure 2 of Appellant's specification appears to show that crystallographic content actually increases as the thickness of Ta increases. The trend of curve [202] from data point [216] to [218] appears to show that the copper crystallographic content at this thickness of Ta actually increases. A lower FWHM value for curve [204] at data point [216] indicates an increased copper crystallographic content. (see specification, page 16 lines 7-16) Thus, Appellant's assertion that a thicker Ta layer would not result in the instant crystallographic content appears contrary to Appellant's own disclosure.

<u>Response to arguments with respect to Group 6, claim 27</u>

Appellant presents the same arguments against the prior art combination. In reply, the examiner reiterates the same position set forth above. Specifically with regard to claim 27,

Appellant submits that none of the references address a distinguishing feature in claim 27, that of a particular Cu <111> crystallographic content. In reply, the examiner notes that the instant crystallographic content for Cu is presently claimed in claims 21 and 23 as well. This limitation is discussed under the examiner's response to Group 5, claims 23-26. Additionally, examiner notes that Appellant's disclosure specified that for the crystallographic content of copper to be at least 70% of that which can be obtained from depositing a copper layer over a pure Ta barrier layer, the Ta barrier layer must be of sufficient minimal thickness. Appellant has provided that a 500 Å thick Ta layer as the barrier layer would result in the overlaying Cu layer to have the instant crystallographic content. (see specification, page 15 lines 13-19) Thus, as Hoshino specifically teaches a Ta layer of sufficient thickness, it was reasonably presumed that the resulting Cu layer would similarly and inherently have the instant crystallographic content.

Arguments directed to the amount of electromigration is not persuasive as this limitation is outside the scope of the present claims.

For the above reasons, it is believed that the rejections should be sustained.

Respectfully submitted,

jam
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